PID Parameter Setting of Servo System based on Genetic Algorithm

Xia Quan-guo, Song Jun and Wang Mao-lin
92941 Unit, huludao, Liaoning, China

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Abstract: In traditional servo control system design, heuristic algorithm is usually adopted to get PID controller parameters. This kind of method consumes long time, needs higher practical work experience, and depends on empirical formula or statistical data. So it is difficult to get good control performance. According to the principle of genetic algorithm, this paper determines optimization range with generalized Hermite -Biehler theorem, and designs the target function by error functional integration evaluation index. MATLAB simulation results show that the setting method is simple and practical, and can get a better control characteristic than the traditional methods.

1 INTRODUCTION

The setting of controller parameters mainly influences two aspects: control quality and robustness of control system. PID controller is simple and practical, has certain robustness to model error, so it's widely applied to the servo control system. For the performance of control system, optimization design and setting of PID controller parameters are crucial. Heuristic algorithm is usually adopted to get PID controller parameters for previous servo control system; this kind of method often has "semiempirical" color. First of all, initial parameters of controller are calculated according to empirical formula or based on some statistical charts, then PID controller parameters are debugged with the method of experiment plus heuristic algorithm, so as to get the expected control performance(REN Ting, JIAO Zi-ping, XU We-ke,2009) .This kind of method is time consuming, needs debugging personnel to have more practical work experience, and relies on empirical formula or statistical data; it is difficult to obtain.

Genetic algorithm is a kind of search method for global optimal probability evolved by referring to the evolution law of biosphere (genetic mechanism of survival of the fittest). It was firstly proposed by American Professor J. Holland (Holland J H, 1975) in 1975; after Goldberg (Goldberg D E, 1989) gave the basic framework of genetic algorithm, widespread interest was aroused in the field of control and this method has been widely used in control field, such as system identification, PID control, optimal control, self-adaptive control, robust control, intelligent control, etc. There are two key technologies to use genetic algorithm to optimize and set PID controller parameters: one is constrained optimization space. Searching appropriate constrained optimization space is directly related to optimization efficiency and results. There is no physical background for controller parameters themselves, so it's difficult to determine the appropriate scope. Considering that the optimization design goal of controller parameters is that control system meets certain index requirements under the circumstance of guaranteeing the stability of control system, this paper adopts generalized Hermite-Biehler theorem to determine the optimization space. The other is reasonable target function. Genetic algorithm measures search effect through fitness function value, which is transformed from target function, and target function reflects the actual control requirements, so target function is a key to the success of algorithm; target function is designed with error functional integration evaluation index by comprehensively considering the requirements of control system, control deviation tending to zero, fast response speed, small overshoot and short rise time.

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2 SERVO CONTROL SYSTEM MODELING

The structure diagram of servo PID control system is as shown in Fig. 1; of which, $u(t)$ is control input, $e(t)$ is error signal, $rin(t)$ is input quantity, $yout(t)$ is output quantity.

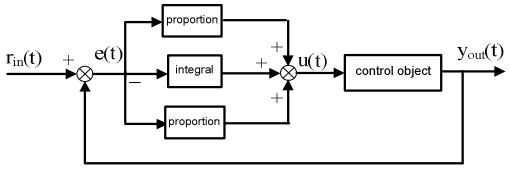

Figure 1: Structure diagram of servo system.

Take the transfer function of controlled object to be(Xu Wenke,Jiao Ziping,Yu Bobiao, 2010)

$$G_p(s) = \frac{92.22}{0.095s^2 + s} \quad (1)$$

The transfer function of PID controller is

$$G_c(s) = k_p(1 + \frac{1}{Ts_i} + T_d s) = \frac{k_d s^2 + k_p s + k_i}{s} \quad (2)$$

In the formula: k_p is proportionality coefficient; T_i is integral time constant; T_d is differential time constant; $k_d = k_p T_d, k_i = \frac{k_p}{T_i}$.

3 SETTING OF PID CONTROL PARAMETERS WITH GENETIC ALGORITHM

3.1 Problem Description

For given controlled object, seek a group of PID controller parameters k_p, k_i, k_d to make the error functional integration evaluation index of controlled system is minimum; target function is used to calculate error functional integration evaluation index and fitness function can be transformed from target function.

3.2 Stability Domain Calculation

In the optimization design of servo control system, first of all, system stability shall be guaranteed. System stability domain refers to the defined range of k_p, k_i, k_d, closed-loop characteristic polynomial is

$$\sigma(s) = 0.095s^3 + (1 + 92.22k_d)s^2 + 92.22k_p s + 92.22k_i) \quad (3)$$

Formula (3) is Hurwitz, i.e. all the roots of polynomial is in open left half plane. Using generalized Hermite-Biehler theorem to calculate the stability domain of control system, we can get the range of

$$k_p, k_i, k_d : k_p \in [0,5], k_d \in [0,2], k_i \in [0,2]$$

3.3 Selection and Realization of Target Function

Target function reflects the actual control requirements; the quality index in the process of transition will make sense only under the given input of zero initial condition and unit step. When the given signal is not a unit step function, quality index in the process of transition will lose its meaning. Moreover, not always single control signal is inputted to the control system, there is also other interference, so it's necessary to build a more common and generalized quality index evaluation function, which is called performance index integration evaluation, which takes instantaneous error($e(t)$)function of control system as functional. In numerous error functional integration evaluation indexes, which on earth is the best choice? Through analysis and comparison on the practicability (whether engineering practical value and calculation are convenient) and selectivity (the bigger, the better for the change of index with the change of parameter) of above performance indexes. So many literatures take ITAE performance index as the optimal performance index for single input single output control system and self-adaptive control system, and it has been widely used. In addition, considering from another way of thinking, once a functional is chosen as the performance index of control system, the corresponding performance index is given to the design system. For example, the minimum quadratic integral functional is applicable to the control system taking minimum energy consumption as the performance index; minimum error absolute value

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integral is applicable to the control system taking minimum fuel consumption as the performance index; minimum integral of error absolute value multiplied by time is applicable to the control system taking fast speed and stability as the performance indexes.

By making use of the advantages of convenient debugging for M file programming in Matlab and the visualization of SIMULINK and being easy to build complex models, system model and ITAE index function value generation module are established in SIMULINK; through the port relationship between M file and SIMULINK module, M file realizes automatic modification of controller parameter and the corresponding ITAE index value is obtained through simulating calculation under this parameter by calling SIMULINK model of the system. The diagram of control system and ITAE index function value generating SIMULINK module is as shown in Fig.2.

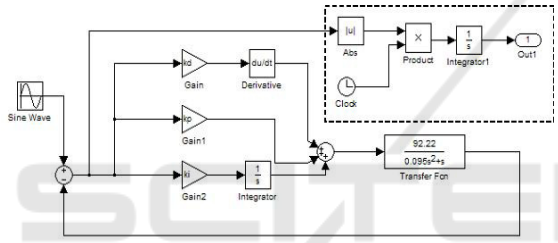

Figure 2: Control system and ITAE index function value generating SIMULINK module.

3.4 Algorithm Flow Block Diagram

PID control parameter setting process based on genetic algorithm is as shown in Fig. 3

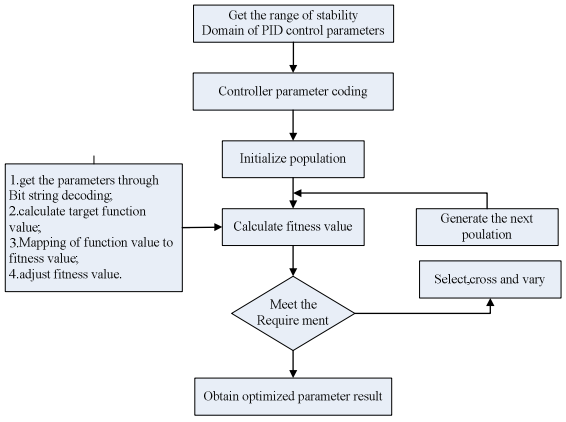

Figure 3: PID control parameter setting process based on genetic algorithm.

4 SIMULATION RESULT

Simulation is conducted by making use of MATLAB genetic algorithm toolbox and evolutionary search convergence begins after the 58th generation, the optimal values kp = 4.884 9, kd = 0.084 36 and ki =0. 084 36 are obtained. To test the control effect of controller, simulation is conducted to tracking error of control system in two kinds of typical input signals including step and sine, system tracking error curves are as shown in Fig 4 and Fig.5.

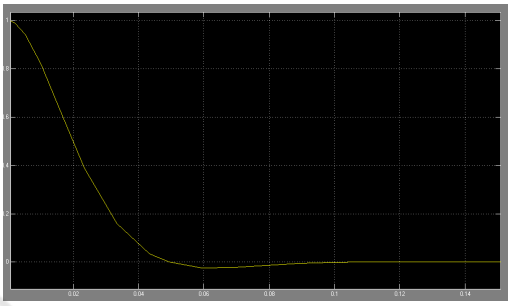

Figure 4: Curve of system tracking error to step signal.

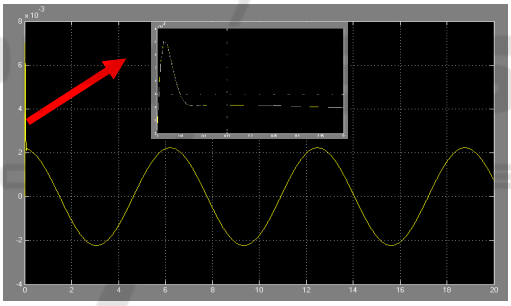

Figure 5: Curve of system tracking error to sinusoidal signal.

We can see from simulation experiment results that servo system has fast response speed and small overshoot; its control deviation tends to zero.

5 CONCLUSION

In this paper, genetic algorithm is applied to the setting of PID controller parameters in servo system. According to the principle of genetic algorithm, first, generalized Hermite-Biehler theorem is used to get the stability domain of PID controller parameters, which not only guarantees the stability of the system, but also determines the optimization space of the algorithm; then, according to the control requirements of servo system, the paper puts forward

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the target function taking ITAE performance index as the algorithm; finally, the feasibility and effectiveness of the method is verified by simulation. This method can provide engineering guidance for engineering design personnel and it has certain engineering application value.

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